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ABSTRACT

In 1990, a study was conducted at Columbia College (CC) to determine whether a predictor variable could be constructed for student nonsuccess in beginning mathematics courses. For the purposes of the study, nonsuccess was defined as earning a grade of D, F, or No Credit either at the time of withdrawal from the course or as a final grade. The ASSET mathematics skills assessment test and a Piaget-based pencil-and-paper test of logical reasoning were administered to 150 students newly enrolled in their first CC mathematics course. Final course grades were collected for 134 of these students. An analysis of the data revealed that a student who obtained "critical scores" on both tests had about a 67% chance of failing the first mathematics course attempted. If only the results of the ASSET test were used, a student who tested "critical" had a 53% chance of failing the first mathematics course. Using both tests offered a better chance of identifying at-risk students. Further statistical analysis suggested that 8% of the variance in grades was accounted for by the ASSET scores alone and that 3% of the variance was accounted for by the Piaget scores alone. Possible explanations for the lack of grade-predictive power of the tests are offered, along with suggestions for further research. (JMC)

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PREDICTING NONSUCCESS IN BEGINNING COLLEGE MATHEMATICS COURSES

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Predicting Nonsuccess In Beginning College Mathematics Courses

For the past two years, Columbia College has used the mathematical skills section of the ASSET assessment battery for screening and placement of students enrolling in mathematics courses. Follow ups on screening and placement have shown that the process too often misses the mark. For example:

a) A student is referred to the Learning Skills Center for remedial work. In less than a month it is clear that the student has well developed reasoning skills and was merely rusty on basic mathematics skills.

b) A student scores above a critical score, follows the recommended placement in a nonremedial mathematics course, and does not succeed in the recommended course.

The student in category a) could have been enrolled in a non-remedial mathematics course and could have used that course's Math Lab to quickly catch up on basics. The student in category b) could have used the Learning Skills Center for a semester in order to develop a solid foundation in the basics.

The ASSET test focuses mainly on skills that require the student to remember and apply basic mathematical operations and algorithms. Very little logical reasoning is required. Because a certain amount of logical reasoning is required of students in

beginning mathematics courses, it is possible that the assessment process would be improved by adding a logical reasoning component. The purpose of this study is to discover whether or not, by using scores from both the ASSET and a Piaget-based pencil and paper test, a variable can be constructed that will predict student nonsuccess in beginning mathematics courses with more reliability than any predictor variable from either test alone. Additionally, it would be useful to discover a sufficiently strong correlation between such a variable and the grades in the first non-remedial mathematics course taken.

An important cognitive development theory that addresses student reasoning ability is the one developed by the Swiss psychologist Jean Piaget (J. Piaget and B. Inhelder, 1958). According to Piaget, human thinking capacity develops in four stages. A few of the reasoning behaviors that distinguish the final two Piagetian developmental stages are listed below (Workshop: Science Teaching and the Development of Reasoning, University of California, Berkeley 1977).

Stages

Concrete Thought	Formal Thought
1. Needs reference to familiar actions, objects and observable properties.	1. Can reason with abstract concepts, indirect relationships or properties, and theories.
2. Needs step-by-step instruction in a lengthy procedure.	2. Plans a lengthy procedure given the goal and resources.
3. Can memorize and then use a simple mathematical algorithm or formula in a familiar context. What an abstract mathematical formula has to say about the system to which it refers is out of reach, here.	3. Can convert an abstract formula into statements about the referred-to real system.

A student who consistently solves problems at the concrete level would be at risk in a first-time nonremedial college mathematics course—the more so, the higher the course level. The accumulated evidence of a decade of studies shows that, of newly enrolled college students, about one-third test at the concrete level, one-third at the transitional level, and one-third have made the transition to formal level thought (McKinnon and Renner, 1971; Lawson et al., 1976; Adi and Pulos, 1980; Song, 1982). A standard Piaget test consists of a series of problem-solving tasks (complete with the real objects presented in the problem) under the guidance of a trained interviewer. It is accurate but very time consuming.

In 1974 G. M. Burney developed and validated a pencil-and-paper test that would perform the same assessment more efficiently because it could be group-administered. The price paid for efficiency is a loss in accuracy, according to Stefanich et. al. (1983). Burney had obtained a Pearson correlation of .85 in establishing concurrent validity with Piagetian task interview scores. In his dissertation, Burney points out that several of the questions in the 24 question test correlate poorly with the Piagetian task test, implying that deletion of these questions would improve the Burney test. Beginning in 1976 a number of researchers have put the Burney test to use with satisfactory results (Curl, 1976; Mehlhorn, 1981; Webb, 1985).

INSTRUMENTATION

The Piaget based pencil-and-paper test used in this research is a slightly modified Burney Logical Reasoning test. Those questions which, according to Burney show poor correlation with Piagetian task interview scores, were deleted. Because there are no control of variables questions in the Burney test, two control of variables questions, similar to the mealworm puzzle used by Lawson (1975), were added. In this paper the resulting 19 question pencil-and-paper test will be called simply the Piaget test and the corresponding test score will be denoted by P. The ASSET test score will be denoted by A.

The ASSET and Piaget tests were administered to 150 students newly enrolled in their first Columbia College mathematics course in the Fall of 1990. The courses involved are Basic Mathematics, Beginning Algebra and Intermediate Algebra. At the end of the semester, course grades (or grades at withdrawal) were collected on 134 of these students. Sixteen withdrew too early in the course for the assignment of a grade. The mathematics instructors were never aware of the Piaget scores and did not request the ASSET scores.

Because the Piaget test is not identical to the Burney Logical Reasoning test it has no predetermined scores for the concrete-transitional and the transitional-formal boundaries. However, if

incoming Columbia College students conform to the national statistics, some 30% should fall below the concrete-transitional boundary score. A score of 9 or below on the Piaget test creates a subset of size 41 which is 30% of the 134 scores being analyzed. This subset of scores will be labelled PC for Piaget Critical. The critical score for the ASSET test is 15. The subset of ASSET scores that are 15 or below will be called AC for ASSET Critical.

ANALYSIS AND CONCLUSIONS

As stated in the introduction, the main purpose of the study is to improve the accuracy with which nonsuccess in the first mathematics course can be predicted. Define nonsuccess (NS) in the course as having earned a grade of D, F, or No Credit either at the time of withdrawal from the course or as a final grade. Thus, the set of 134 students is composed of two mutually exclusive subsets, NS (nonsuccessful) and S (successful). In general, this study proposes that knowing a student scored critical on either diagnostic test increases the ability to predict nonsuccess, and knowing the student scored critical on both tests further increases the ability to predict nonsuccess. More formally:

> Hypothesis 1: The proportion of nonsuccessful students who score critical on only one of either the ASSET or Piaget tests is higher than the overall proportion of nonsuccessful students.
>
> Hypothesis 2: The proportion of nonsuccessful students who score critical on both the ASSET and Piaget tests is higher than the proportion who score critical on only one of the tests.

A Venn diagram can display every possible subset involving the categories S and NS and the various test score categories for the data obtained in this study.

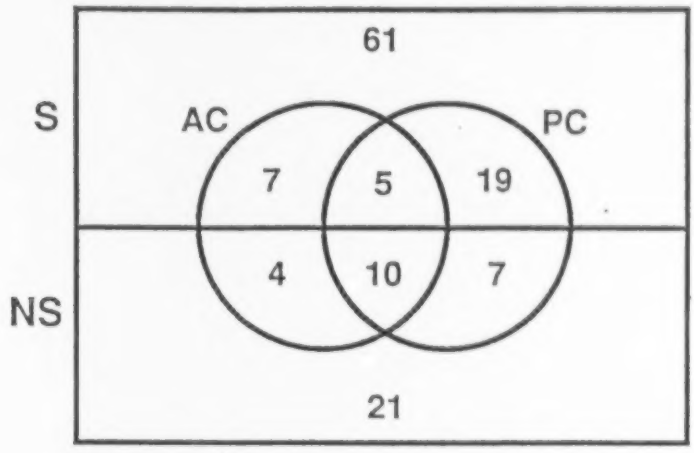

Figure 1. Venn diagram showing frequency per set category

The left circle contains all of the students obtaining critical scores on the ASSET test and the right circle contains the Piaget Critical students. A computation of the various proportions yields:

Overall proportion of NS students	= 42/134	= 0.31
Proportion of NS students who scored critical on Piaget test only	= 17/(24+17)	= 0.41
Proportion of NS students who scored critical on ASSET test only	= 14/(12+14)	= 0.54
Proportion of NS students who scored critical on both ASSET and Piaget tests	= 10/(5+10)	= 0.67

Before addressing the question of chance fluctuations, notice that the proportion of nonsuccess, given that both test scores

are critical, is indeed larger than the other proportions of nonsuccess. This says that a student who obtains critical scores on both tests has about a 67% chance of failing the first mathematics course attempted. Without reservation, the student should be referred to the Learning Skills Center to bring him/her up to speed on skills and (it is hoped) provide experiences that will stimulate a shift into the Piagetian "transitional thought" stage. If there is only the ASSET test score to work with, a student who tests "critical" has a 53% chance of failing the first mathematics course. It is not as easy to decide what to recommend here. What logical reasoning skills the student might possess can only be guessed.

Table 1. Observed frequencies.

	Crit. A&P	Crit. A only	Crit. P only	pass A&P	Totals:
S	5	7	19	61	92
NS	10	4	7	21	42
Totals:	15	11	26	82	134

The contingency table in Table 1 contains the same information as the Venn diagram. Notice that the first column category, Crit. A&P, (AC and PC) has its frequency entries reversed – 10 nonsuccessful and 5 successful – relative to the other test score categories. A chi-squared analysis of the data (X^2_{obs} = 10.3, df=3) rejects the null hypothesis (i.e., that the observed

differences in proportions are due to chance) at the α=.02 level. In other words, the size of the observed differences in proportions of nonsuccessful students would have occurred by chance only 2 times out of 100. Since the overwhelming contribution to the chi-square test statistic comes from the "AC and PC" category cells, it is clear that using both tests offers a better chance of identifying at-risk students.

Table 2. Expected frequencies.

	Crit. A&P	Crit. A only	Crit. P only	pass A&P	Totals:
S	10.3	7.55	17.85	56.3	92
NS	4.7	3.45	8.15	25.7	42
Totals:	15	11	26	82	134

A note of caution is in order. Table 2 lists the frequencies that would be expected if the population S/NS ratio were the same across categories. One of the assumptions of the chi-square procedure is that the sample size be large enough that the expected frequency in each cell be 5 or more (Pagano, 1986). It can be seen that the two left-most cells in the bottom row contain expected frequencies less than 5. However, the numbers are close and this can be regarded as a minor violation of the assumptions.

A second question that can be answered, here, is what percent of the variance in grades can be account for by the test scores,

separately and in concert? Seeing the separate Grade vs. ASSET and Grade vs. Piaget scattergrams (Figures 2 and 3), it is easy to guess that very little correlation between grade and test score exists. Treating the grade scale A=4, B=3, C=2, D and F=1 and the test scores as interval data (legal, according to Johnson and Creech, 1983), simple linear regression analysis produces r^2=0.078 (p=.01) for grade vs. ASSET and r^2 = 0.027 (P = .05) for grade vs. Piaget. That is, only 8% of the variance in grades is accounted for by the ASSET scores alone and 3% by the Piaget scores alone. A stepwise multiple regression analysis shows that bringing in the Piaget scores (to act with the ASSET scores) results in no significant gain in r^2.

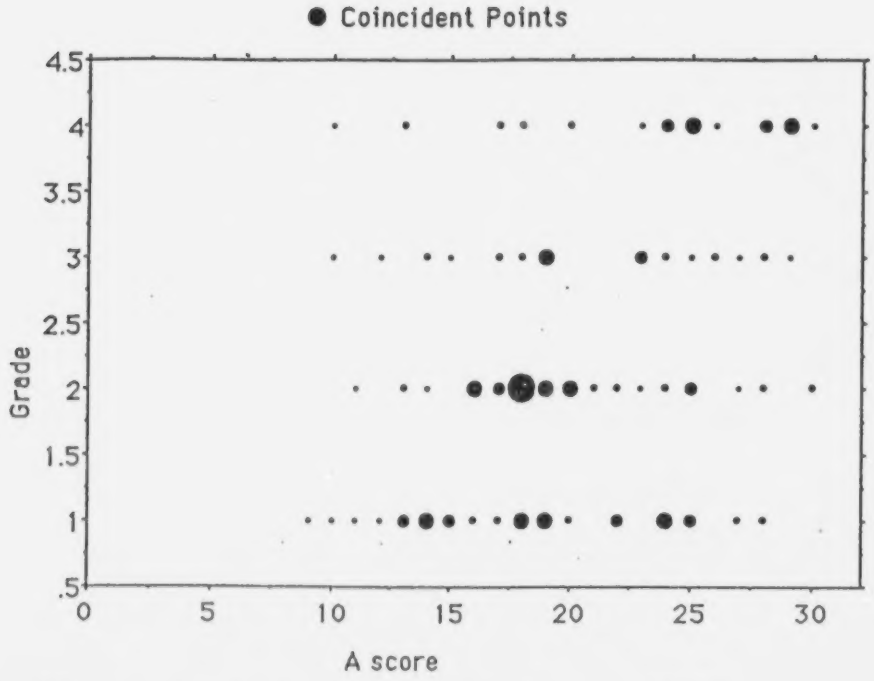

Figure 2. Scattergram of Grade vs. ASSET score.

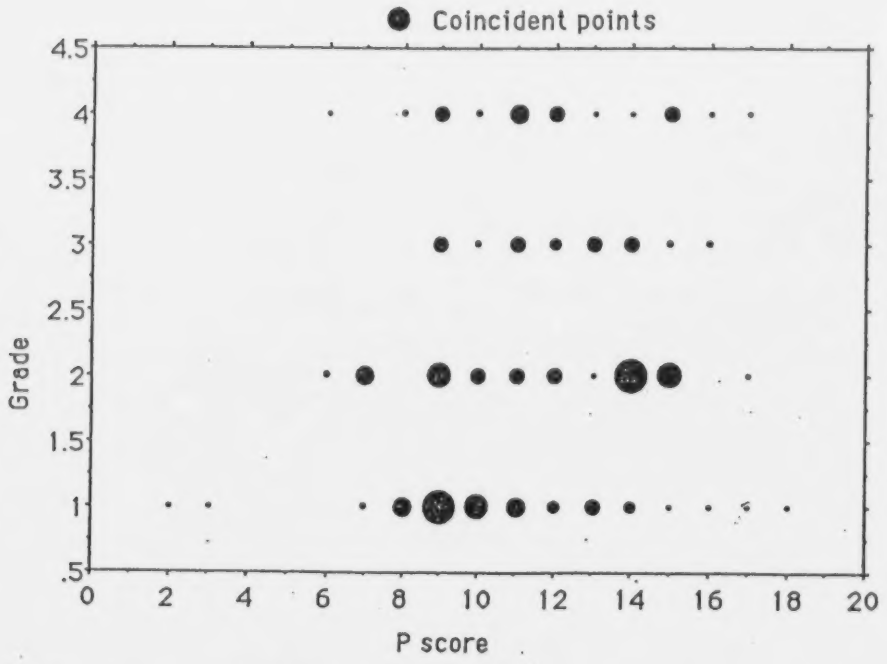

Figure 3. Scattergram of Grade vs. Piaget score.

A study by Webb (1985) at California State College, Bakersfield finds $r^2 = 0.34$ for grade in beginning algebra vs. Burney Logical Reasoning score and $r^2 = 0.18$ for grade in general education math vs. Burney Logical Reasoning score, both much larger than the 0.027 found in this study. Predicting 34% of the variance in grade is certainly more satisfying than predicting 3% of the variance. It is a disappointment to say that in this study neither the ASSET test nor the Piaget test has any real grade predicting power except that, for the subset of students whose scores are critical on both tests, 70% can be predicted to fail their first course.

Speculation is offered on what may be lowering the coefficient of determination in the single and multiple regression analyses. Return to Figures 2 and 3. Imagine how they would look if there were a trend in each from lower left to upper right producing a "respectable" coefficient of determination, say, $r^2 = 0.30$. Now, a look at the actual plots reveals at least one group of points that upsets the hoped for trend. In both Figures, at the grade=1 height, this is the set of points that is to the right of the test's critical score, A=15 for Figure 2 and P=9 for Figure 3. To see these points from a second perspective, imagine a three dimensional scatter plot with grade as the vertical axis as sketched in Figure 4.

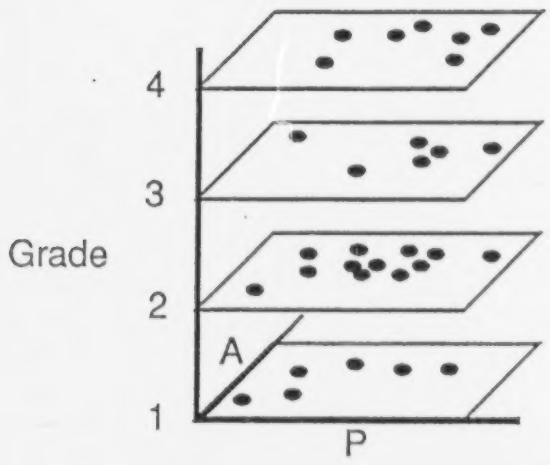

Figure 4. Multivariable scattergram geometry.

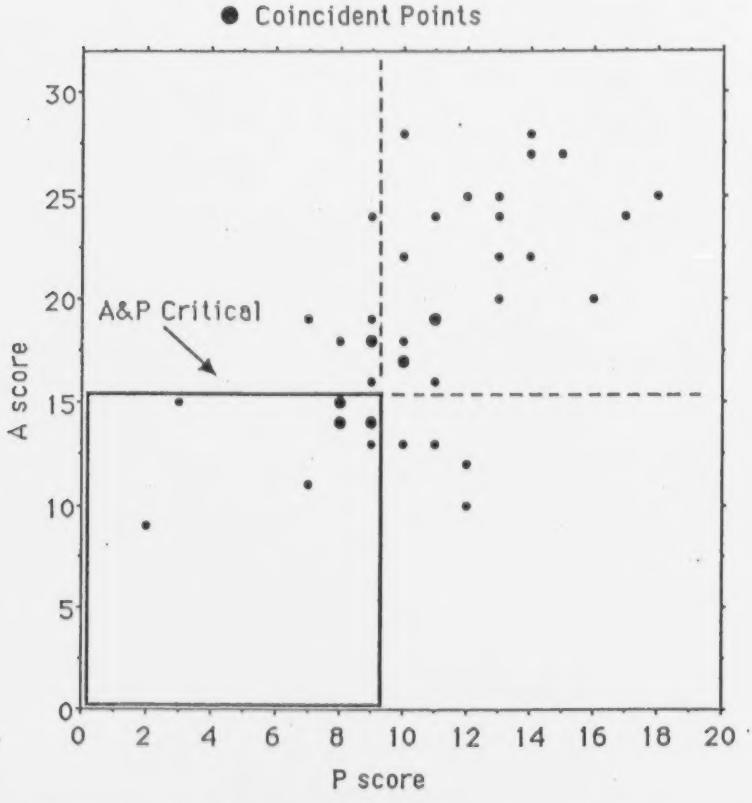

Figure 5. ASSET vs. Piaget at Grade = 1 plane.

Figure 5 is the bottom plane (Grade=1). Each point in the plane gives the ASSET and Piaget score. The fat points are double points. The points that upset the trend are the 21 points inside the dashed box in the upper right. The test scores of all 21 students exceeded the critical scores of both tests and yet they all failed their first mathematics course. What happened?

Three extreme possibilities are offered for the wide variance in grades per test score:

(1) The tests do not do what they are supposed to do. The problem is with the tests.

(2) The tests would have grade prediction power with a "normal" population. The Columbia College population is unusual in that those other variables responsible for the variation in grades take on more extreme values in this population.

(3) The logical thinking a student is required to do in the beginning mathematics courses to get a C, B, or A is too easy or too difficult or varies widely from course to course.

Keep the above three grade variance speculations in mind as recommendations for future research are considered.

RECOMMENDATIONS FOR RESEARCH

1. Return to the 21 students whose test scores exceeded

critical and who failed their first course. Assume that grade variance speculation (2) above applies to this case.

Conduct candid interviews of the 21 students to uncover key variables that contribute to the unexpected reversal, high test scores—low mathematics grade. Review the literature before designing the interview, this kind of study has certainly been done before in a broader context. The students could be brought in on the goal of the research and they could be paid for their time. The interviewer could be one of the school's counselors. When the important variables are identified, a short carefully written questionnaire, to be attached to the assessment tests, could be produced. Some of the 21 students might be of assistance in testing the wording.

2. This recommendation is motivated by grade variance speculation number (3) above. Create for mathematics courses an inventory whose results indicate what percents of graded student work, for course grades of "C" and "A", require Piagetian concrete and formal thought processes. The most reliable method of getting the inventory data might be to interview the instructor. The interviewer should be familiar with course content and the Piagetian Taxonomy.

3. Create a friendly, computer administered Piaget test that is truly interactive (as near to a live Piagetian task interview as possible) by using one of the new interactive

multimedia courseware authoring tools such as Course Builder (Macintosh), SuperCard (Macintosh), or Authorware Professional (Macintosh or IBM PC). Test the computer Piaget instrument for concurrent validity with the Piaget task interviews.

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